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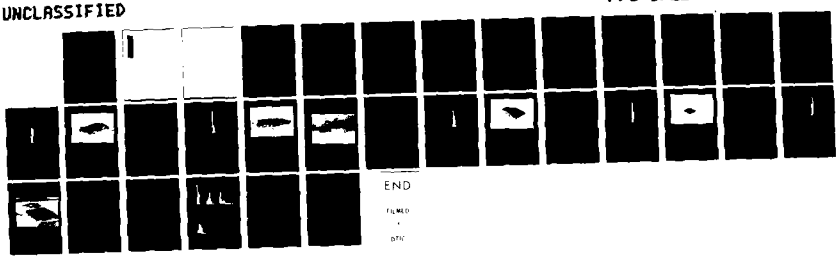

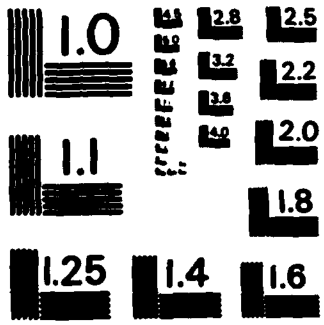

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16. Abstract

In 1980 six satellite-tracked buoys were deployed on icebergs along the coast of Greenland. One of these icebergs was in the Denmark Straits east of Greenland while the remaining five were in Baffin Bay. The icebergs were tracked using System ARGOS. The drift speeds near Greenland rarely exceeded 0.20 m/s with speeds less than 0.10 m/s being most common. The speed of the one iceberg that drifted to the North American side of Baffin Bay was higher (up to 0.[illegible] m/s) after reaching the western side of Baffin Bay. The data supports a conclusion that icebergs reaching the western side of Baffin Bay came from glaciers north of 74-30N. The icebergs tracked were grounded for 63% of the time tracked.

17. Key Words: Baffin Bay, Denmark Strait, iceberg drift, Greenland, iceberg, speed

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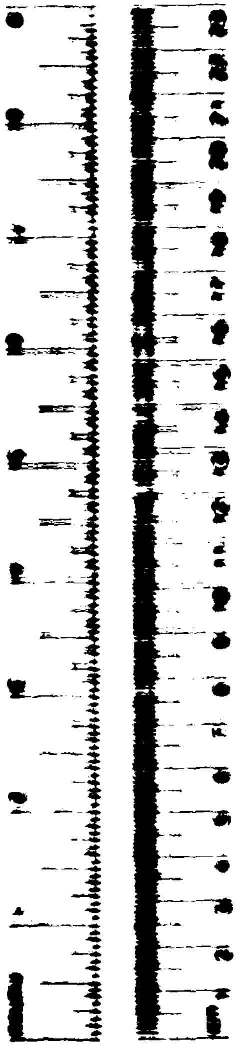

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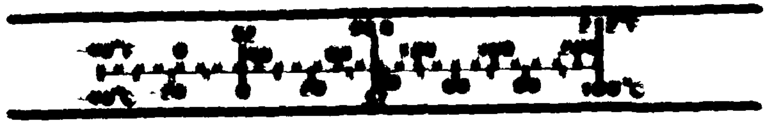

ACKNOWLEDGEMENTS

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1.0 INTRODUCTION

Icebergs produced by Greenland's glaciers travel in the coastal currents around the island. The currents are generally southward along the eastern coast of Greenland and northward along the western or Labrador Sea and Baffin Bay coast. Icebergs are carried to the western side of the Davis Straits and Baffin Bay by westward flowing branches of the West Greenland Current system. Icebergs then follow the southward flowing Baffin Island and Labrador currents along the continental margins of North America until they finally melt in the Labrador Sea or the waters of the Grand Banks.

In order to gain a more detailed picture of the drift and fate of Greenland icebergs a program of direct satellite tracking of icebergs was started in 1977. The details of these drifts are presented in Robe and Maier (1979). The icebergs which were tracked in the experiment covered by that report were initially located on the western side of the Davis Straits area or near Disko Island, Greenland. The results of that study showed that the speed of a drifting iceberg is highly variable with those icebergs on the North American side generally moving faster than icebergs near Disko Island. Icebergs along the North American coast traveled at speeds up to 0.80 m/s while those near Disko Island never exceeded 0.40 m/s. The modal speeds, however, were much less than these, being 0.10 to 0.20 m/s and less than 0.10 m/s, respectively. However, a greater variability exists in the drift direction than in the drift speed between the icebergs near Disko Island and those along the North American coast. While all of the icebergs grounded frequently, those on the North American side progressed steadily toward the south. The icebergs near Disko Island on the other hand showed a drift that repeatedly looped back on its previous track and showed little net movement over the tracking period.

On 31 January 1980, two satellite-tracked buoys were deployed by parachute. An attempt was made to place them on icebergs northwest of Disko Island. Because of high surface winds the deployment was unsuccessful. However, one buoy landed on sea ice and continued to transmit for 26 days, eventually drifting southeast until grounding on the main island of Greenland to the south of Disko Island.

An effort to track icebergs in regions not covered in the 1977-78 experiment was undertaken in 1980. The USCGC WESTWIND, on its 1980 Arctic East deployment to Greenland waters, was to be used to deploy satellite-tracked buoys along the southeast coast of Greenland and also in Baffin Bay north of Disko Island and south of Cape York. This region of western Greenland contains eight of the nine major iceberg-producing glaciers of West Greenland (Kollmeyer, 1978). One buoy was deployed to the east of Greenland while five were deployed in Baffin Bay (Figure 1). All deployments were made by landing an HH52 helicopter of the USCGC WESTWIND on the iceberg and setting the buoy on the ice.

In August 1981, during a joint exercise of the USCGC WESTWIND and the USCGC EVERGREEN, two buoys were recovered and one was redeployed onto a new iceberg.

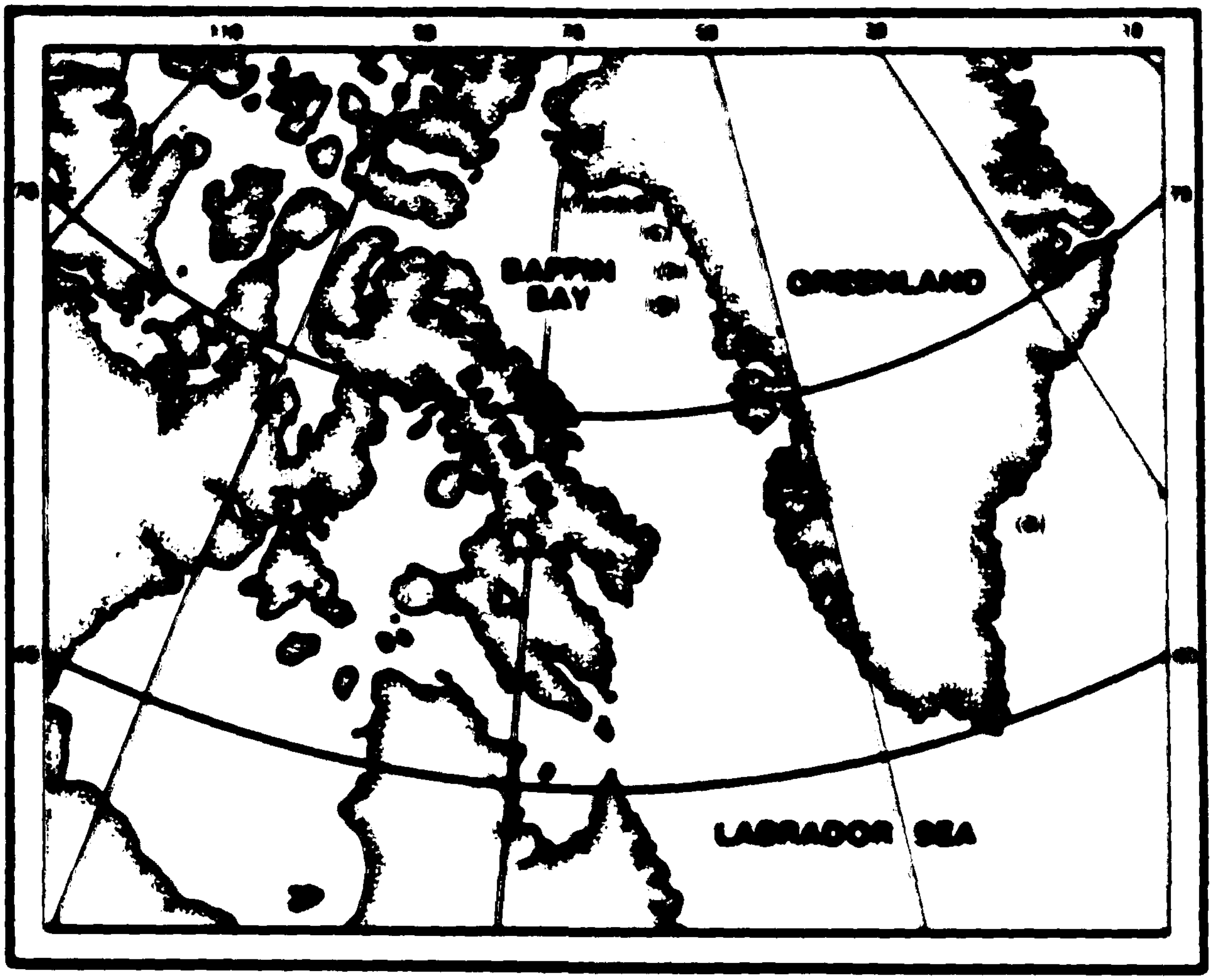

FIGURE 1. Approximate deployment locations for satellite-tracked buoys on Greenland icebergs. (a) Platform number 2577; (b) Platform number [illegible]; (c) Platform number 2575, first deployment; (d) Platform number 2578; (e) Platform number 2579; (f) Platform number 2576; (g) Platform number 2575, second deployment.

2.0 SYSTEM ARGOS

System ARGOS (Bessis, 1981) is a Franco-American agency set up in 1978 for the purpose of processing the output from data collection platforms using the TIROS-N/NOAA-A satellite systems for location determination and data relay. System ARGOS provides data processing and relay services for users by contract between these users and ARGOS. This system replaced and upgraded the earlier NIMBUS tracking and data relay system. The NIMBUS system was essentially an experimental proof-of-concept system operated by NASA.

System ARGOS attempts to have two-satellite coverage at all times. Two satellites in the latitude range of 60°N to 75°N provides 9 to 12 positions per day. The constraints on the above horizon time for an acceptable position

fix is that the satellite must be above the horizon long enough to receive five Doppler messages with a minimum of 420 seconds between the first and last message (Bessis, 1981).

Position accuracies are approximately $\pm$ 150 m at one standard deviation and $\pm$ 500 m at three standard deviations for a transmitter oscillator stable to 10^{-9}. The transmitters used in this experiment have this stability or better. System ARGOS appears to have no systematic errors (Bessis, 1981).

3.0 DATA PROCESSING

Platform position data from System ARGOS were both accurate and free of obvious gross errors.

The number of positions received for a 24-hour period could range from zero, due to some system failure, up to 20 or 21 positions. A more typical number would be nine to twelve positions per day. These positions are not, however, equally spaced in time. This makes them less than ideal for analysis purposes and can also lead to quite high velocities when the positions are closely spaced in time. As a consequence positions which were closer together in time than 15 minutes were considered duplicates and one was eliminated.

The position data were then processed as in Robe and Maier (1979). The records of latitudes and longitudes were separately converted to equally time spaced records by using a four-point linear interpolation scheme. Values of latitude and longitude were determined every three hours. Since the orbit time for the TIROS/NOAA satellites was approximately 102 minutes, all data points were used in at least two interpolations.

The interpolated time series of positions with the three-hour time step was then filtered using a low-pass filter with a cut-off frequency of 1.16×10^{-5} Hz or one cycle per day. This effectively removed variations in current due to inertial and tidal influences and other system errors. Drift speeds and directions were computed from the filtered file on a 12-hour basis. This presented a series of 12-hour average velocities with no component with a frequency higher than 1.16×10^{-5} Hz.

The use of the filter effectively reduces the record length by approximately four days which is a disadvantage for very short drift tracking periods.

4.0 DEPLOYMENT

The satellite-tracked ice buoys were prepared for deployment on board the USCG Cutter NORTHWIND. Icebergs suitable to receive a buoy were those which were thought to be fairly stable because of their large horizontal dimensions, smooth enough to allow a helicopter to land, and in deep enough water so that the iceberg was not grounded. As will be seen in later discussion it was not always possible to guess whether an iceberg was either freely floating or stable. An effort was made to deploy the buoys in a slight depression so that the buoy would not slide off due to minor rotation of the iceberg. It was discovered that small steel legs fastened to the corners of the buoy base increased the resistance to sliding on the ice.

The deployments in 1980 were conducted by the HH52 helicopters of the USCG Cutter NORTHWIND. The 1981 recovery of two buoys and the redeployment of one of them was conducted by the air detachment aboard the USCG Cutter WESTWIND.

The buoys were equipped with batteries for an expected two-year life.

5.0 BUOY PLATFORM NUMBER 2577

Buoy number 2577 was deployed at 1100Z, 11 August 1980 (Julian Day 224). The position of the iceberg at the time of deployment was 65-19.4N, 36-05.0W. The iceberg measured 1000 meters by 500 meters with an above water height of 30 meters. This iceberg was the only one which was tracked on the eastern side of Greenland. The iceberg was tracked for less than a month. The filtered drift data covers a period of twenty-one days (Figure 2). The net drift during the tracking period is almost exactly due south approximately 39 miles east of Kulusuk, Greenland. The details of the drift show a half circle path toward the east which connects two southerly legs both to the north and the south. Two apparent grounding episodes occurred on days 229 to 232 and from day 246 to day 247. The 12-hour average speeds (Figure 3) were all less than 0.15 m/s and 97% were less than 0.10 m/s. The iceberg was aground during 20% of its observed drift.

6.0 BUOY PLATFORM NUMBER 2580

Buoy number 2580 was deployed at 1300Z, 22 August 1980 (Julian Day 235). The position of the iceberg at the time of deployment was 73-19N, 57-11W. The iceberg measured 500 meters by 325 meters with a freeboard of 30 to 60 meters (Figure 4). The drift track of the iceberg tracked with buoy 2580 (Figure 5) was confined to an area of less than one degree of latitude. After drifting northwestward from the point of buoy deployment the iceberg was grounded repeatedly on a 200 meter shoal from approximately day 282 (1980) to day 359 (1980). At this time tracking was lost due to low signal strength. On day 100 (1981) tracking was resumed with the iceberg again aground on a 200 meter shoal 30 miles to the south. On day 124 (1981) the iceberg drifted free and drifted almost due north for approximately 20 days before undergoing a circuitous drift toward the southwest. On day 210 (1981) the buoy was picked up by a helicopter from the USCG Cutter WESTWIND. This iceberg's drift speed reflects the low currents that are present, with 71% of the speeds being less than 0.08 m/s and none being higher than 0.15 m/s (Figure 6). From the drift track (Figure 5) it is evident that there is little consistent background current and that a large part of the drift is in response to the wind. This track is similar to those near Disko Island in 1977 and 1978 (Robe and Maier, 1979). For 44% of the total drift period the iceberg was grounded.

When the buoy was recovered the cause of the weak signal was found to be a defective coaxial cable.

7.0 BUOY PLATFORM NUMBER 2575

Buoy number 2575 was deployed at 1900Z, 25 August 1980 (Julian Day 238). The position of the iceberg at the time of deployment was 75-29N, 59-30W. The iceberg measured 500 meters by 275 meters with an above water height of 41 meters (Figure 7). This iceberg never moved between the time of deployment and time of recovery of platform 2575 on 1 July 1981.

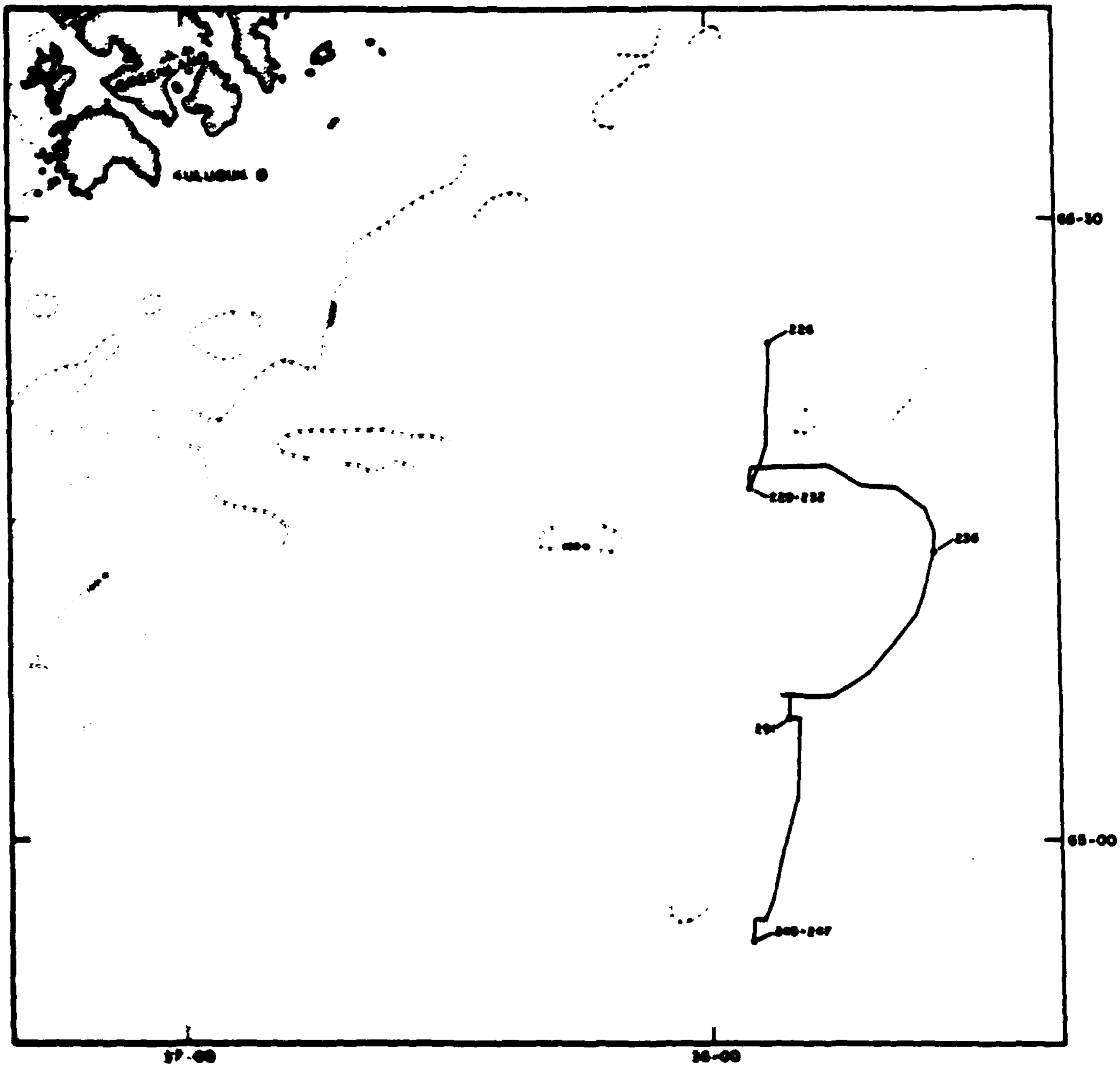

FIGURE 2. Iceberg drift tracked by buoy platform number 2577 off the east coast of Greenland. (Dates on the trackline are in Julian dates. All occur in 1980.)

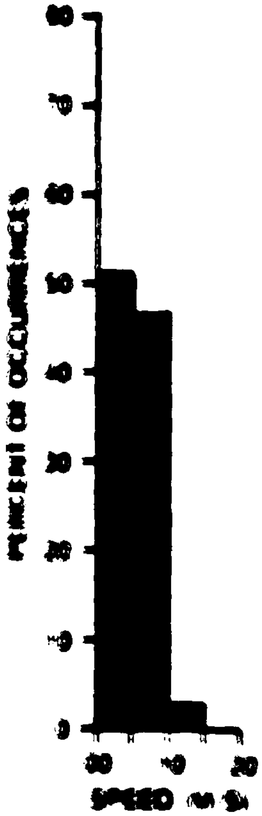

FIGURE 3. Distribution of 12-hour averages of iceberg speeds for buoy platform number 2577.

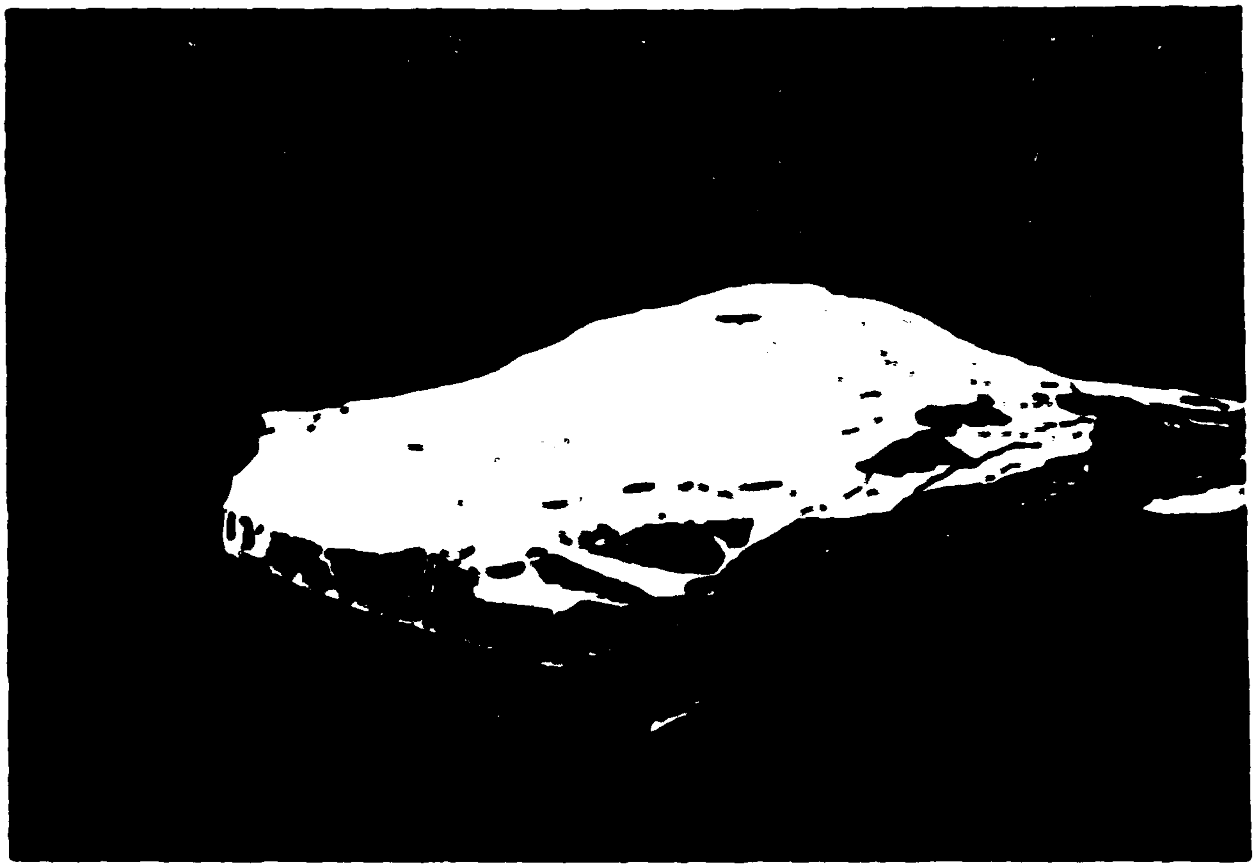

FIGURE 4. Iceberg tracked by buoy platform number 2580.

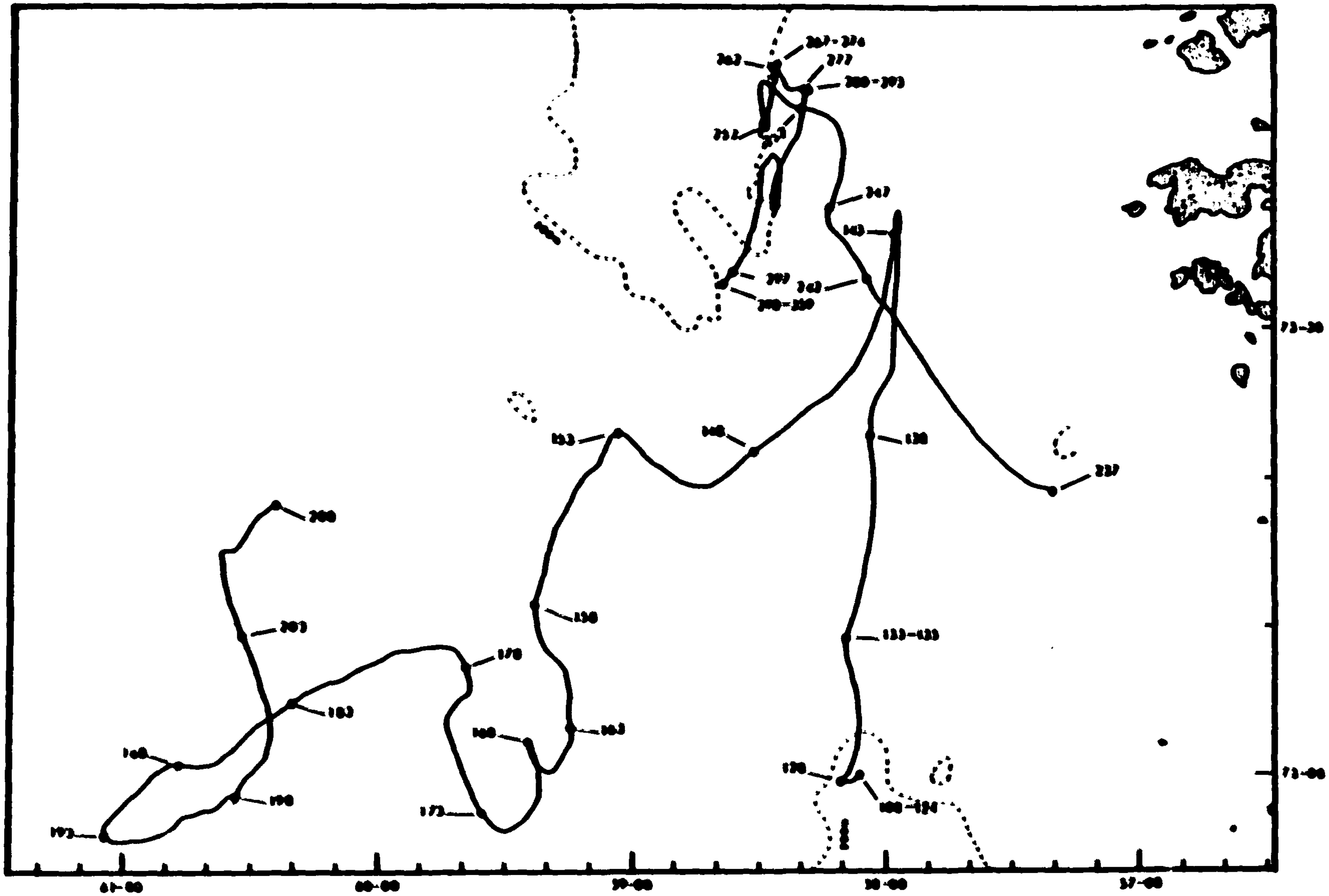

FIGURE 5. Iceberg drift tracked by buoy platform number 2580 off the west coast of Greenland. (Dates on the trackline are Julian dates. Dates run from 237 to 359 in 1980 and 108 to 208 in 1981.)

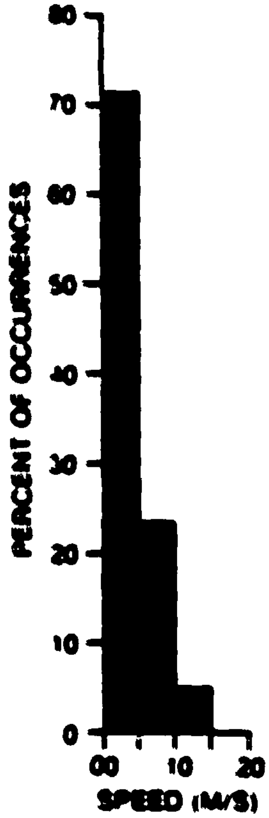

FIGURE 6. Distribution of 12-hour averages of iceberg speeds for buoy platform number 2580. Groundings are excluded.

FIGURE 7. Iceberg tracked by buoy platform number 2575, first deployment on 25 August 1980.

This buoy platform was redeployed by the USCG Cutter WESTWIND on 2 August 1981 (Julian day 214). The position at the time of redeployment was 73-09N, 62-19.2W. The iceberg measured 396 meters by 213 meters with an above water height of 65 meters (Figure 8). The drift track of the iceberg (Figure 9) was generally in the northward direction from the start until day 341 (1981). Although the net drift was to the north, east-west excursions near 74N were of a scale comparable with the northward drift.

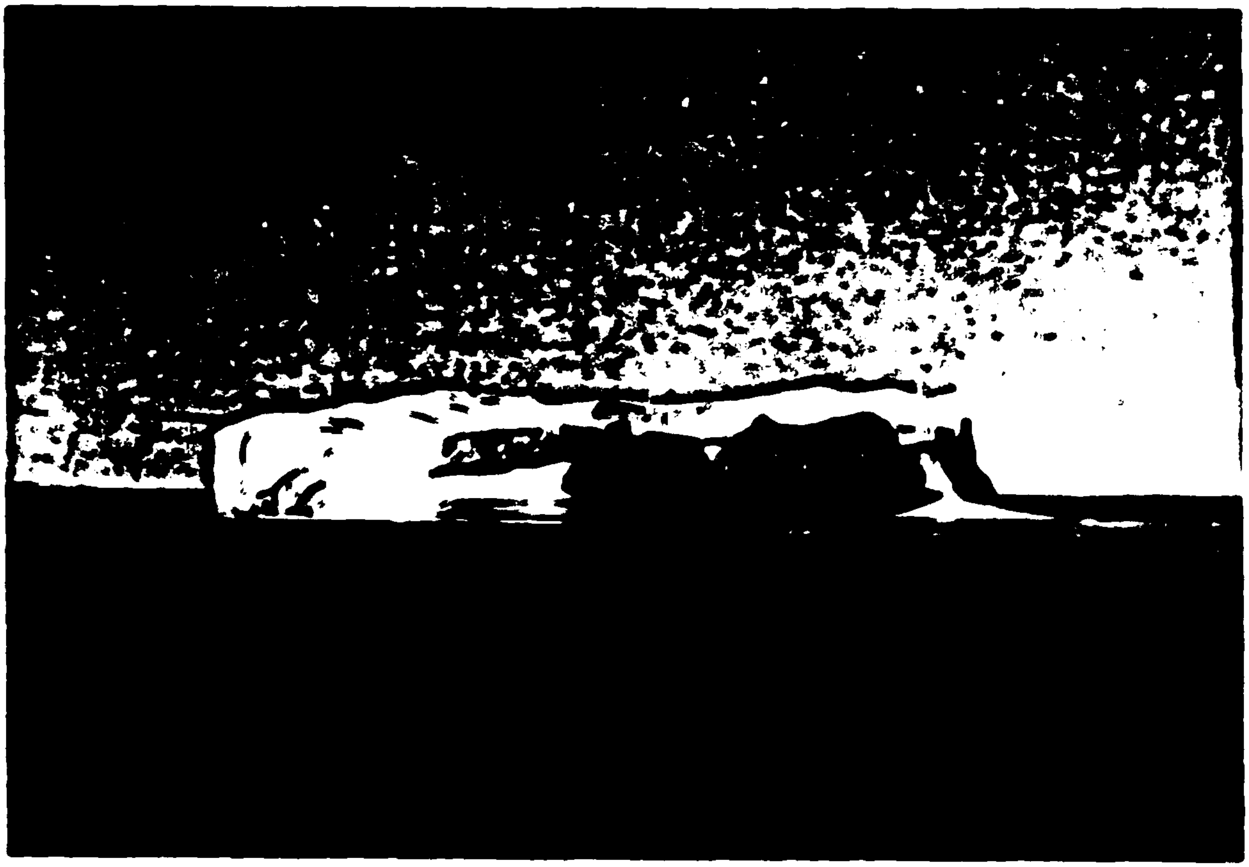

FIGURE 8. Iceberg tracked by buoy platform number 2575, second deployment on 2 August 1981.

North of 74N the drift track is as highly changeable as that of platform 2580. Little net movement is observed through day 106 (1982). Only one possible grounding event occurred. That was from day 005 to 087 (1982). If the iceberg in fact grounded it would have a draft of nearly 250 meters. As of this writing (23 June 1982) the iceberg is drifting in nearly the same location. The drift speeds (Figure 10) of the iceberg were typical of those found off the West Greenland coast. 53% of the 12-hour averages of speed were below 0.05 m/s, grounding events being excluded. An additional 36% were between 0.05 and 0.10 m/s. No speeds over a 12-hour period exceeded 0.25 m/s. The highest speeds occurred during a strong northwest drift between day 291 and day 296 (1981). This iceberg was aground during 32% of its observed drift.

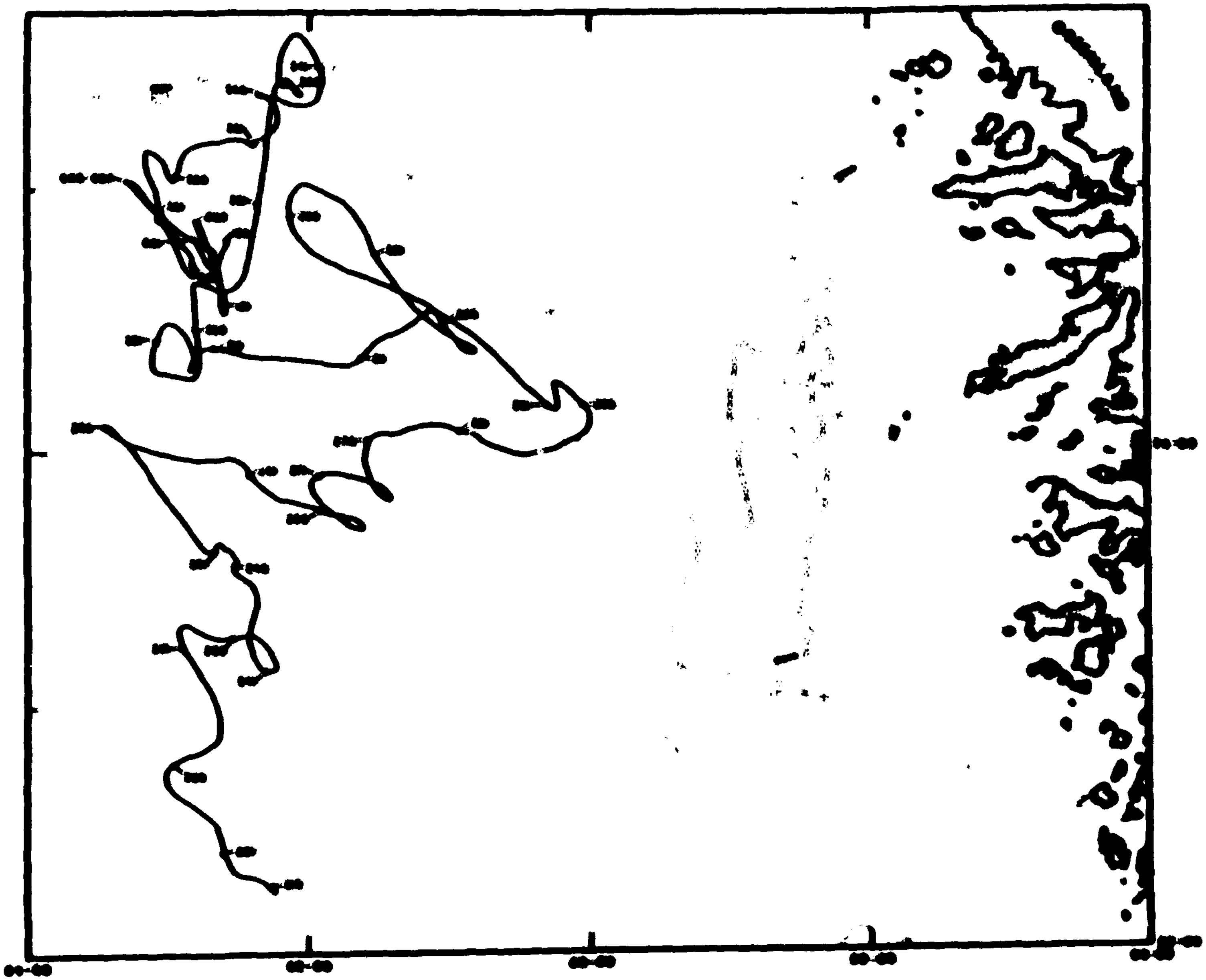

FIGURE 9. Iceberg drift tracked by buoy platform number 2575 during its second deployment off the west coast of Greenland. (Dates on the trackline are Julian dates. Dates begin with 216 in 1981 and end with 106 in 1982.)

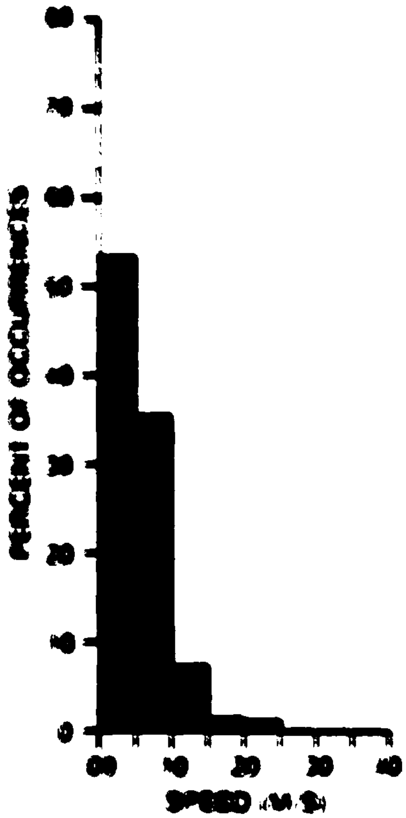

FIGURE 10. Distribution of 12-hour averages of iceberg speeds for buoy platform number 2575. Groundings are excluded.

8.0 BUOY PLATFORM NUMBER 2578

Buoy number 2578 was deployed at 1800Z, 24 August 1980 (Julian Day 237). The position of the iceberg at the time of deployment was 74-50.9N, 58-58.0W. The iceberg measured 280 meters by 220 meters with a freeboard of 27 to 53 meters (Figure 11). The drift track of this iceberg (Figure 12) follows a path toward the northwest. Since the iceberg was tracked for only about twenty days it is impossible to determine to what extent it is moving in a uniform current flow along the Greenland coast. However, there is an indication that north of 74-30N the flow direction appears to be less variable. During the rather short tracking period the maximum speed did not exceed 0.10 m/s (Figure 13) with speeds less than 0.05 accounting for 68% of those measured. This iceberg did not ground during the tracking period although it drifted in an area with many shoals.

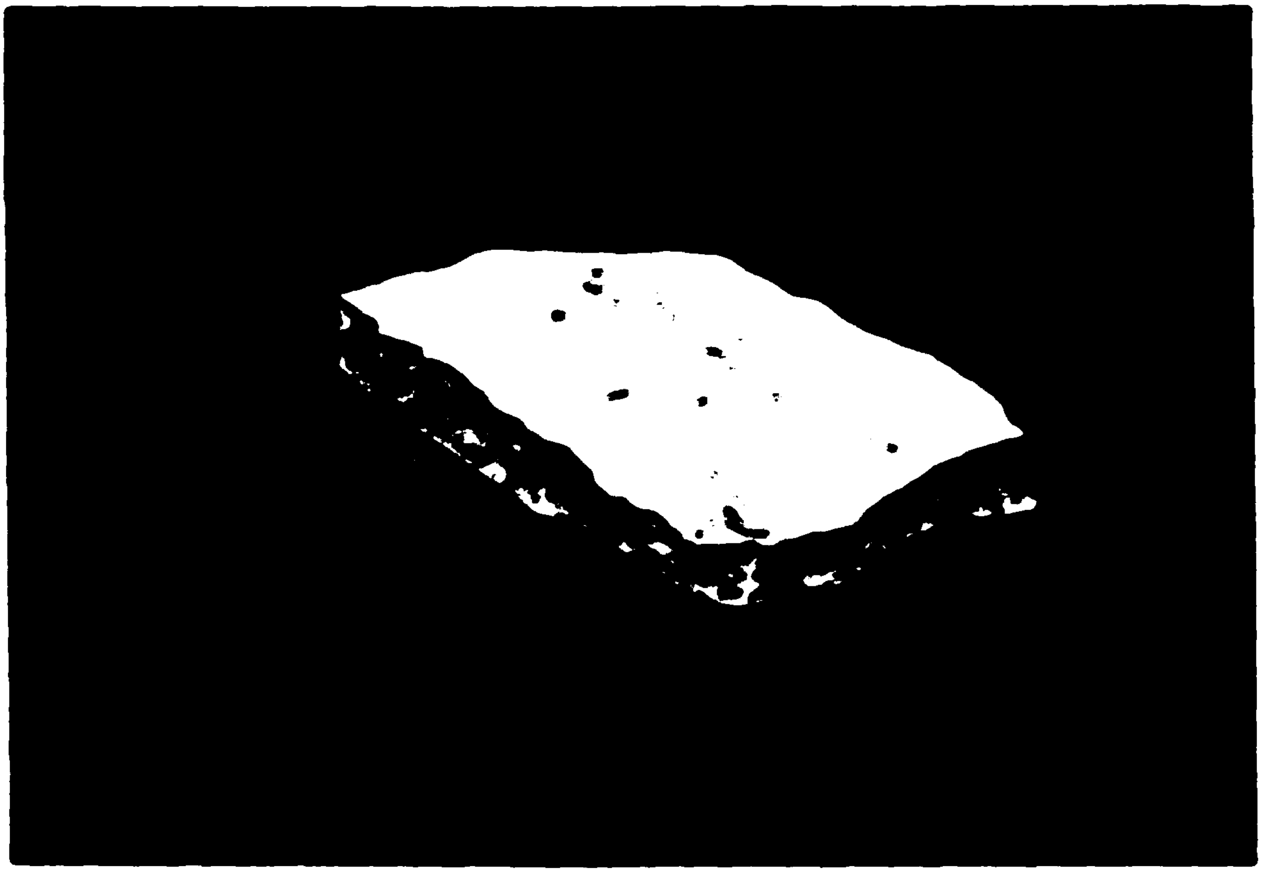

FIGURE 11. Iceberg tracked by buoy platform number 2578.

9.0 BUOY PLATFORM NUMBER 2579

Buoy number 2579 was deployed at 1530Z, 25 August 1980 (Julian Day 238). The position of the iceberg at the time of deployment was 75-34.9N, 61-00W. The iceberg measured 380 meters by 310 meters with an above water height ranging from 30 to 60 meters (Figure 14). The drift track for this iceberg (Figure 15) was predominately east to west paralleling the coast of Greenland in northern Melville Bay. While the tracking period is only slightly over two weeks it shows the more orderly coastwise movement seen north of 74-30N in eastern Baffin Bay. The speeds (Figure 16) were never higher than 0.10 m/s, but the modal value of speed was between 0.05 and 0.10 m/s instead of less than 0.05 m/s as for buoy number 2578. The speed was between 0.05 and 0.10 m/s 60% of the time. This iceberg was aground during 40% of the observed drift.

10.0 BUOY PLATFORM NUMBER 2576

Buoy number 2576 was deployed at 1600Z, 28 August 1980 (Julian Day 241). The position of the iceberg at the time of deployment was 75-54.0N, 63-00.4W. The iceberg was the largest of the West Greenland icebergs tracked,

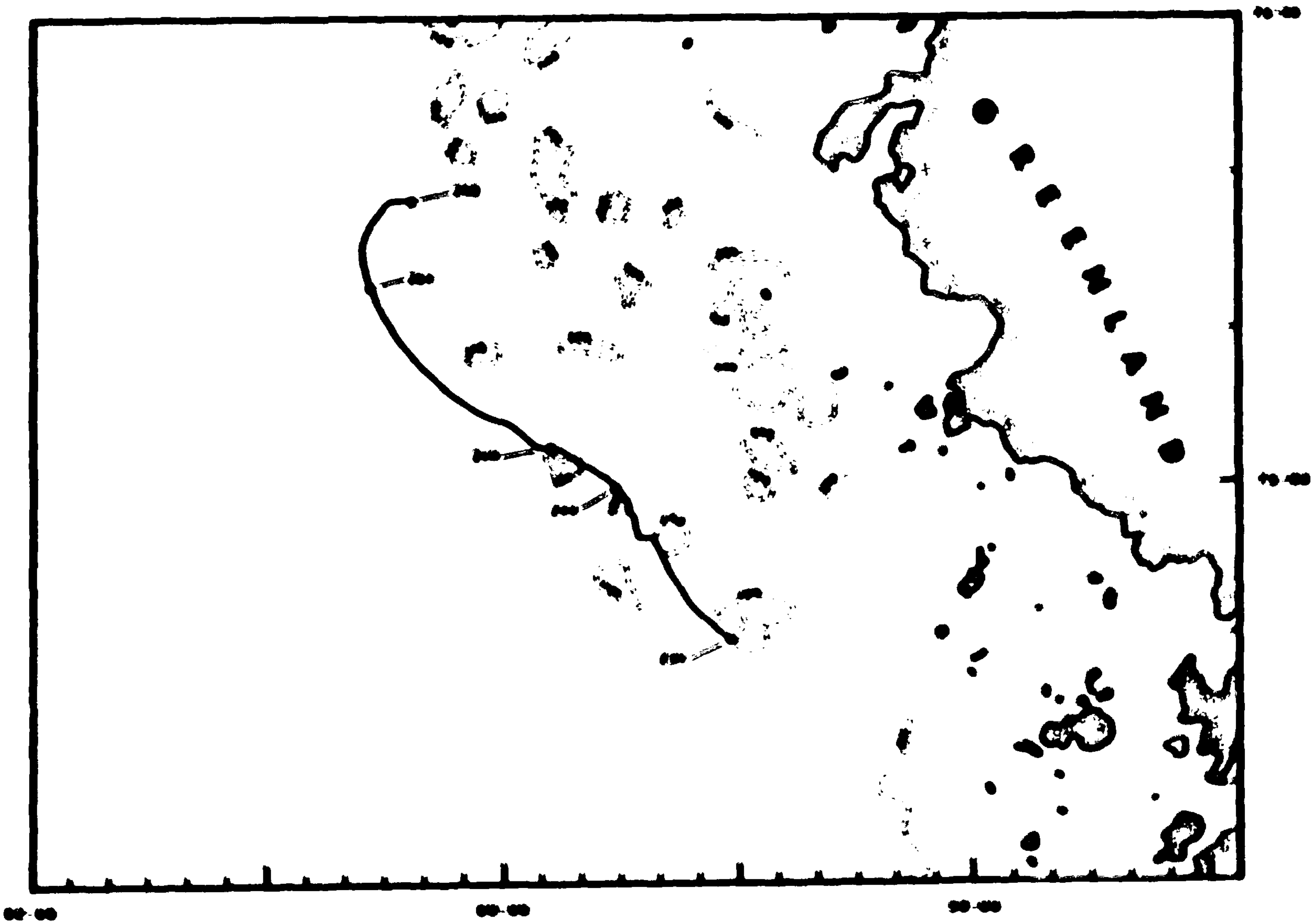

FIGURE 12. Iceberg drift tracked by buoy platform number 2578 during 1980 off the west coast of Greenland. (Dates on the trackline are Julian dates.)

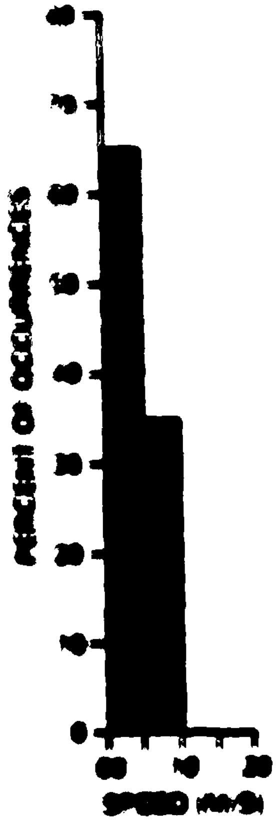

FIGURE 13. Distribution of 12-hour averages of iceberg speeds for buoy platform number 2578. Groundings are excluded.

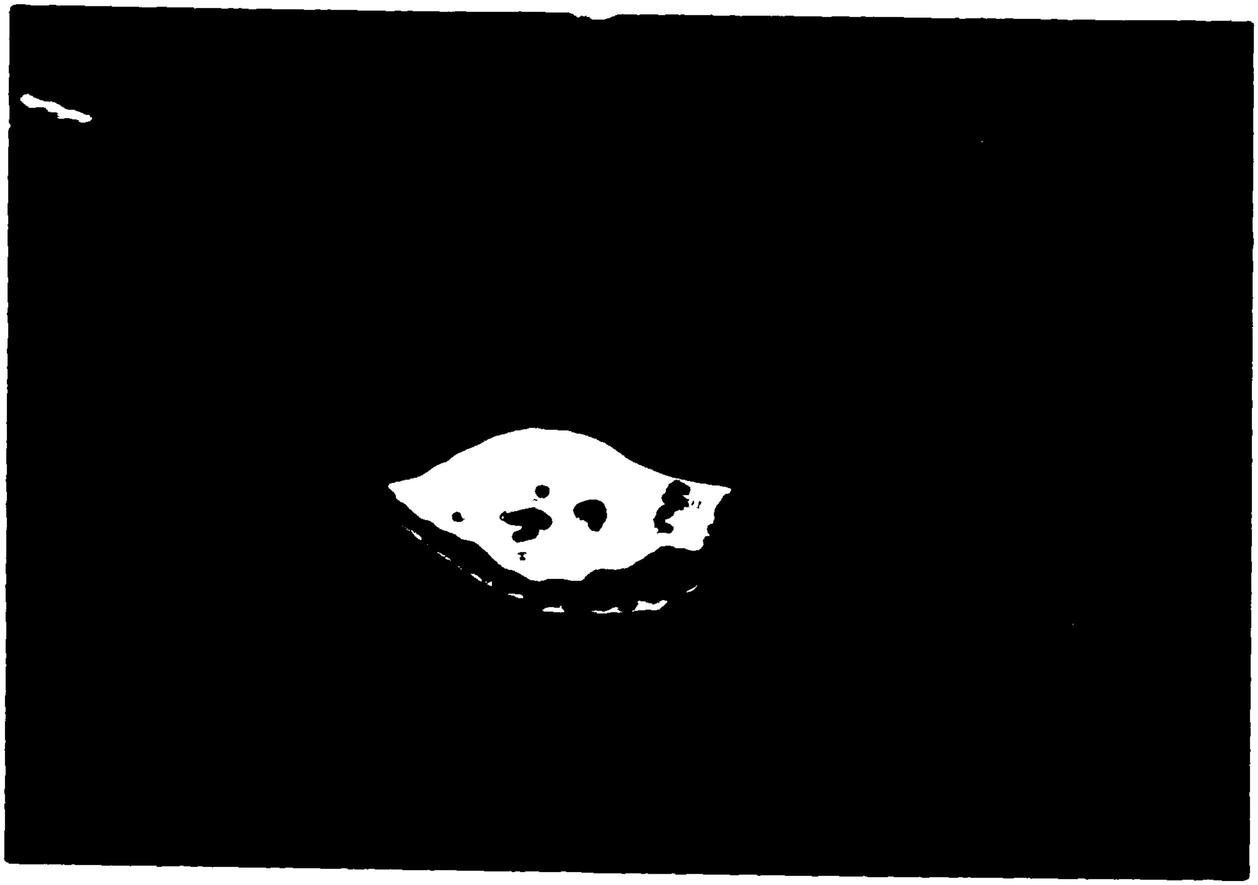

FIGURE 14. Iceberg tracked by buoy platform number 2579.

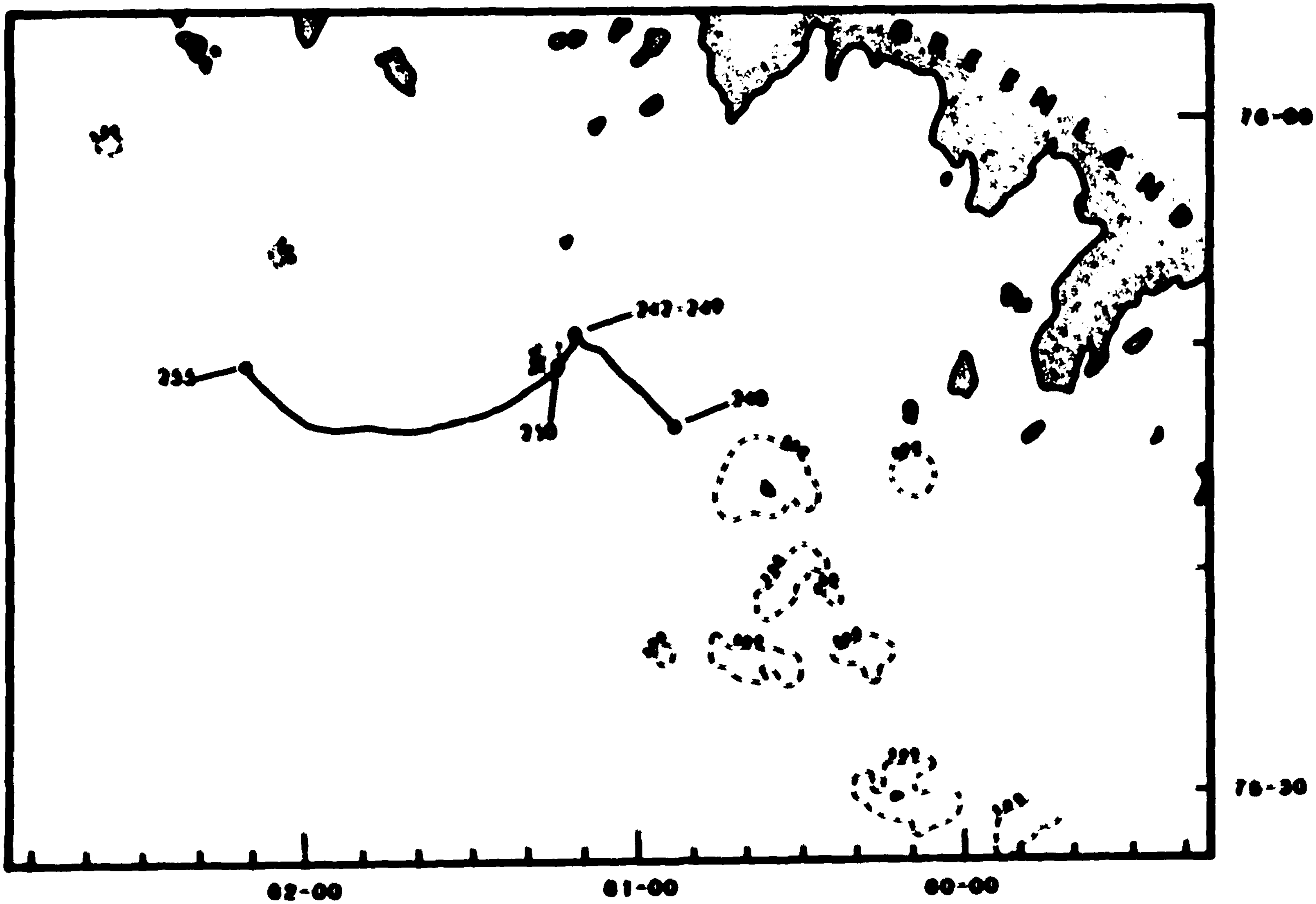

FIGURE 15. Iceberg drift tracked by buoy platform number 2579 during 1980 in Melville Bay. (Dates on the trackline are Julian dates.)

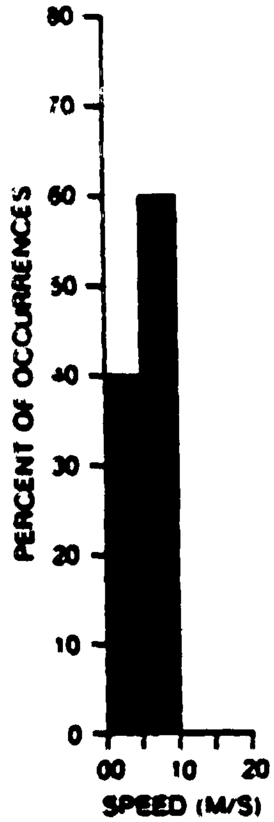

FIGURE 16. Distribution of 12-hour averages of iceberg speeds for buoy platform number 2579. Groundings are excluded.

measuring 900 meters by 600 meters and having a freeboard of approximately 35 meters (Figure 17). Of all the icebergs tracked this one lasted the longest and drifted the farthest. At press time the buoy is still transmitting from the last position on Figure 18 where the iceberg has been aground since 22 December 1981.

FIGURE 17. Iceberg tracked by buoy platform number 2576.

10.1 Day 243 (1980) to Day 210 (1981)

The iceberg was aground 15.5 nautical miles south of Kap Edvard Holm in Melville Bay when the buoy was deployed. It remained aground in this position until Julian Day 256. At this point the iceberg drifted along the edge of the shoal area 2-3/4 nautical miles toward the southwest. On the same shoal area the iceberg again grounded in 200 to 250 meters of water. On this shoal (75-51.7N, 63-02.8W) the iceberg remained grounded from Julian Day 259 of 1980 until Julian Day 168 of 1981. After drifting free of the shoal the iceberg followed a path very closely aligned with the bathymetry in Melville Bay (Figure 18). The drift speed (Figure 19a) in Northern Melville Bay is quite slow with 63% of the speeds falling below 0.05 m/s and only 3% exceeding 0.10 m/s.

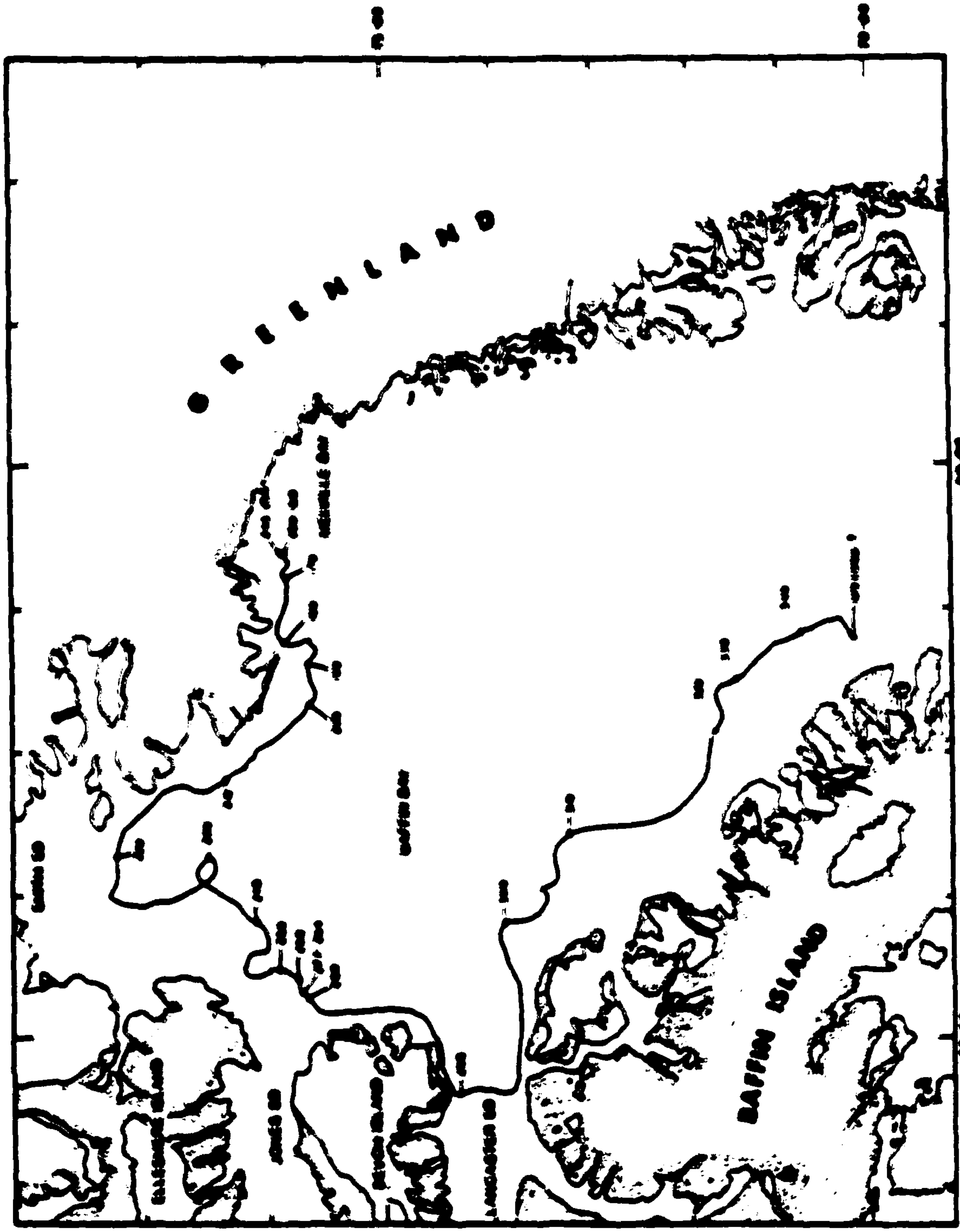

FIGURE 18. Iceberg drift tracked by buoy platform number 2576 during 1980, 1981 and 1982. (Dates on the trackline are Julian dates. The dates begin with day 243 in 1980 and end with day 109 in 1982.)

FIGURE 18. Trackline of Platform 2576

10.2 Day 211 (1981) to Day 257 (1981)

Upon leaving Melville Bay the iceberg drifts northwestward into the northern portion of Baffin Bay which borders Smith Sound. The drift continues to closely follow the bathymetry. The iceberg reaches its northernmost latitude at 77-13.9N, 75-03.2W as it crosses the southern end of Smith Sound and begins the southward drift along the coast of Ellesmere Island. During the portion of the drift between Melville Bay and the waters of Jones Sound the iceberg's speed increased as did its variability (Figure 19b). The modal speed being between 0.10 and 0.15 m/s during 39% of the 12-hour averaging periods. The highest speeds, between 0.30 and 0.35 m/s, occurred as the iceberg turned south after reaching its northernmost point. It is interesting to compare these speeds in the southern part of Smith Sound with those recorded for sea ice movement during April of 1975 (Ito and Muller, 1982). The mean speed of sea ice movement in this area as measured from satellite imagery was 0.06 m/s or about half that noted for the iceberg of 0.14 m/s. The maximum speed for the sea ice was 0.40 m/s in the direction of 188°T while the iceberg had a maximum speed of 0.32 m/s with a direction of 167°T. These maximum velocities are quite comparable and appear to occur in southern portions of Smith Sound east of Ellesmere Island.

10.3 Day 257 (1981) to Day 319 (1981)

This portion of the drift takes the iceberg from the entrance of Jones Sound along the coast of Devon Island across Lancaster Sound to the point where a southward drift along the Baffin Island continental shelf begins (Figure 18). The drift is interrupted between days 277 and 284 by a grounding on a shoal off the entrance to Jones Sound. The iceberg moves quite slowly near Jones Sound for the 30-day period from day 258 to day 288. This slowness could be caused by the iceberg dragging on the bottom in addition to the period when it was completely stopped. After day 288 the iceberg moved freely and quite rapidly along the Devon Island coast entering Lancaster Sound on the north side within two miles of the Devon Island shore. The iceberg then drifted almost due south across Lancaster Sound and exited the sound on the southern side. The iceberg's speed during this portion of the drift (Figure 19c) was higher and more variable than in Melville Bay or Baffin Bay/Smith Sound. The modal speed was between 0.00 and 0.05 m/s, a circumstance which can be accounted for by the slow drift or intermittent grounding off Jones Sound. If these speeds were eliminated from Figure 19c the modal value of speed would be between 0.05 and 0.10 m/s and the distribution would be quite flat between the lowest and highest speeds. The maximum speeds between 0.50 and 0.65 m/s were experienced as the iceberg left Lancaster Sound on the southern side. Riggs, et al., (1980) reported current of up to 0.70 m/s on the southern side of Lancaster Sound.

10.4 Day 319 (1981) to Day 109 (1982)

During this portion of the drift the iceberg closely followed the continental margin southward offshore of Baffin Island (Figure 18). On day 356 (1981) the iceberg grounded at 70-09.5N, 66-00W as of this writing on day 176 (1982) it is still grounded in that area. The speed of the iceberg along the coast of Baffin Island is highest at the Lancaster Sound end of the track. The speeds are less variable than further north (Figure 19d).

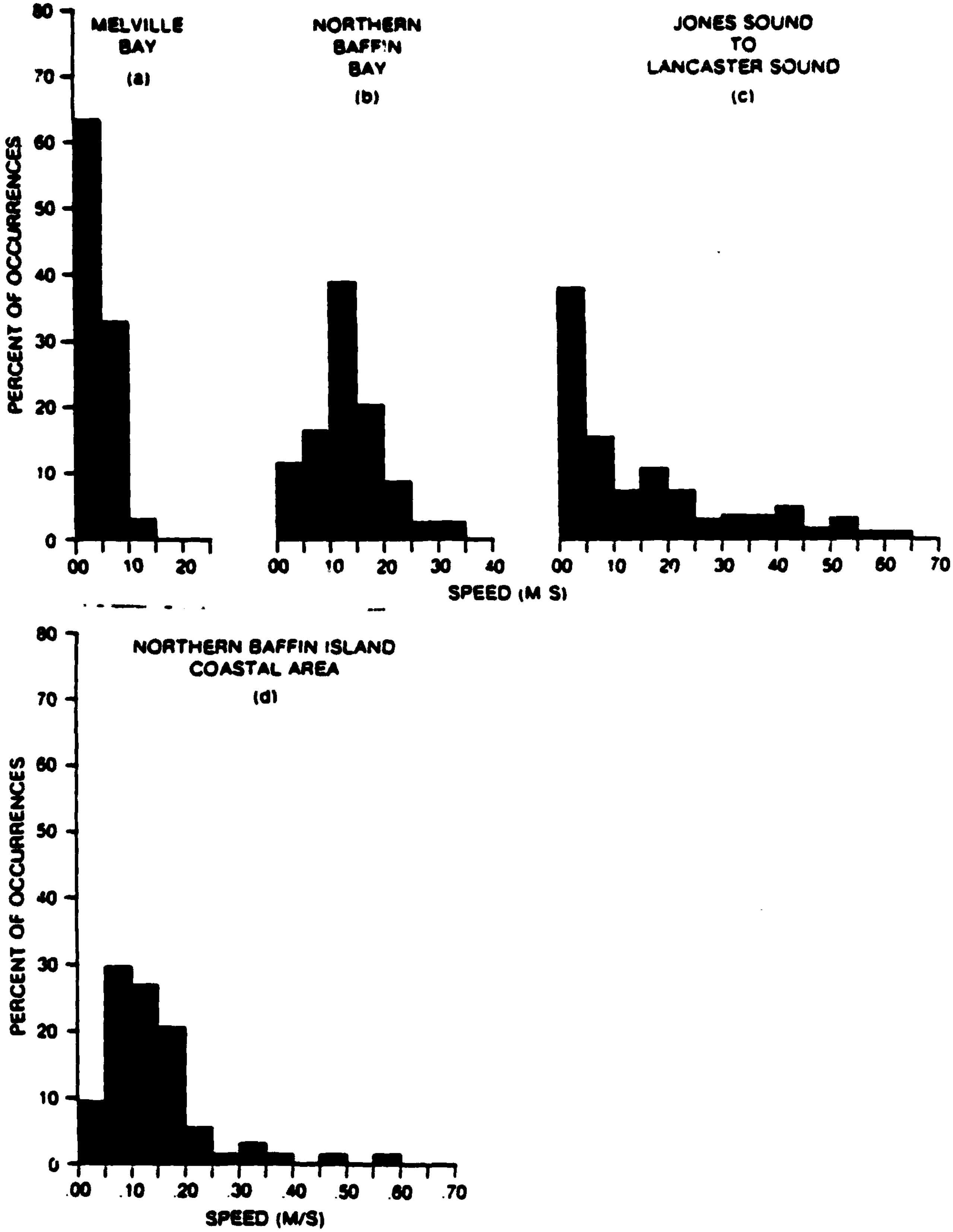

FIGURE 19. Distribution of 12-hour averages of iceberg speeds for bouy platform number 2576. Groundings are excluded. Time periods covered by sub-figures are as follows: a) 1200Z, day 243, 1980, to 1200Z, day 210, 1981; b) 0000Z, day 211, 1981, to 0000Z, day 257, 1981; c) 1200Z, day 257, 1981 to 0000Z, day 319, 1981; d) 1200Z, day 319, 1981, to 0000Z, day 109, 1982.

The modal speed is between 0.05 and 0.10 m/s accounting for 29.5% of the 12-hour intervals. The interval between 0.05 and 0.20 m/s accounts for 77% of the 12-hour periods. The maximum speed was 0.58 m/s.

During the entire tracking period from day 243 (1980) to day 110 (1982) this iceberg was grounded 69% of the time.

11.0 CONCLUSIONS

As was noted in Robe and Maier (1979) the drift speed of icebergs along the Greenland coast rarely exceeded 0.20 m/s. Most of the time the icebergs drifted in Greenland coastal waters at speeds less than 0.10 m/s.

If the drift tracks in Robe and Maier (1979) in the vicinity of Disko Island are combined with the tracks in this report it is possible to propose a pattern of drift in Baffin Bay. It appears that south of 74-30N but north of Davis Straits icebergs move erratically with little evidence of a mean drift. An argument can be made that in this region of Baffin Bay currents and, by extension, icebergs respond to local winds.

North of 74-30N the drift was coastwise toward the north and west in much of the Melville Bay portion of Baffin Bay. As the icebergs move out of Melville Bay toward Ellesmere Island current speed increases and becomes more variable while the path of drift becomes more purposeful. The greatest speeds occur where the iceberg is affected by the outflow of Lancaster Sound and by the Baffin Island current.

The icebergs grounded frequently and for long periods of time during their drift. A figure of 40% was given in Robe and Maier (1979). The time grounded for icebergs in this report varied from 0% to 100% of the period tracked. A weighted mean for time grounded was 63%.

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